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STIRAP for Nuclear Physics?

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R.P. de Groote
Prof. dr. G. Neyens



Outline

- STIRAP as Abbreviation
- STIRAP in Motivation
- STIRAP in Theory
- STIRAP in General Physics
- STIRAP in Nuclear Physics?
- STIRAP in Conclusion

Abbreviation Motivation Theory General Physics Nuclear physics

STIRAP as abbreviation

STIRAP
= STImulated
Rapid
Adiabatic
Passage

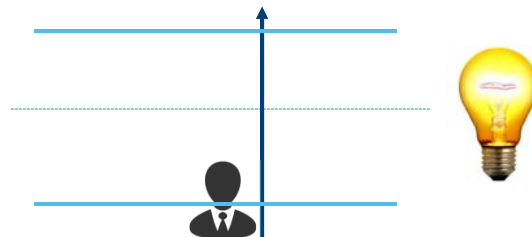
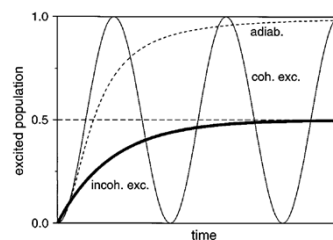
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Abbreviation Motivation Theory General Physics Nuclear physics

STIRAP in Motivation

- Laser spectroscopy in nuclear physics
- Incoherent excitation
- Coherent excitation



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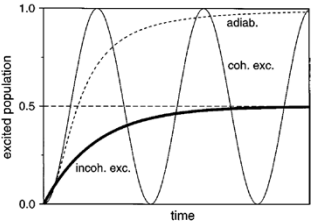
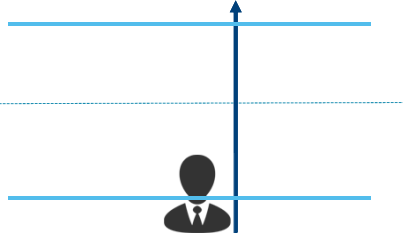

K. Bergmann et al. Rev. Mod. Phys. (1998)

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Abbreviation
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STIRAP in Motivation

- Laser spectroscopy in nuclear physics
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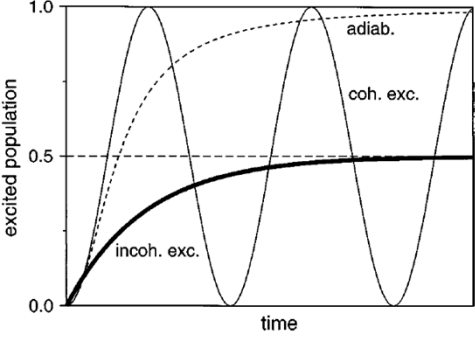
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K. Bergmann et al. Rev. Mod. Phys. (1998)

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STIRAP in Motivation

- Incoherent excitation
- Coherent excitation
- STIRAP excitation

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STIRAP in Theory

- STIRAP Hamiltonian

$$H(t) = \frac{\hbar}{2} \begin{bmatrix} 0 & \Omega_P(t) & 0 \\ \Omega_P(t) & 2\Delta_P & \Omega_S(t) \\ 0 & \Omega_S(t) & 2(\Delta_P - \Delta_S) \end{bmatrix}.$$

Coupling strength induced by

- Stokes laser
- Pump laser

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K. Bergmann et al. Rev. Mod. Phys. (1998)

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STIRAP in Theory

- STIRAP Hamiltonian

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Detuning

- Stokes laser
- Pump laser

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STIRAP in Theory

- STIRAP Hamiltonian

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(a)

(d)

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Abbreviation
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STIRAP in Theory

- Quantum description

$|a^0\rangle = \cos \Theta |1\rangle - \sin \Theta |3\rangle,$

$\tan \Theta = \frac{\Omega_P(t)}{\Omega_S(t)}.$

(a)

(b)

= 0

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STIRAP in Theory

- Adiabatic following

"A physical system remains in its instantaneous eigenstate if a given perturbation is acting on it slowly enough compared to the gap between the eigenvalue and the rest of the Hamiltonian's spectrum".

$|\dot{\Theta}| \ll |\omega^\pm - \omega^0|.$

➔

$\Omega_{\max} T \geq 10^*$

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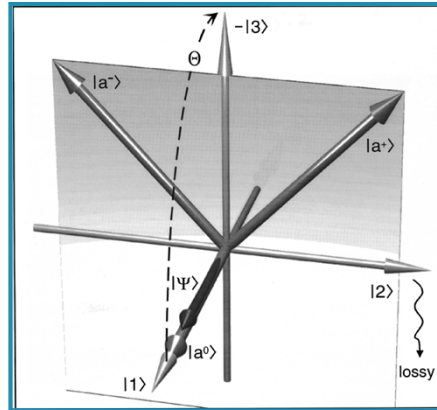
B.M. et al. Zeitschrift für Physik (1928)

*In the case of transform limited bandwidth

Abbreviation Motivation Theory General Physics Nuclear physics

STIRAP in Theory

- Adiabatic following



$$|a^0\rangle = \cos \Theta |1\rangle - \sin \Theta |3\rangle$$

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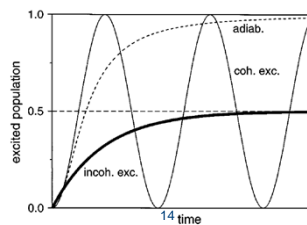
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bandwidth

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STIRAP in General Physics

- STIRAP presents
 - Efficient excitation
 - Robust excitation
 - Excitation to 1 photon forbidden states
 - Relative insensitivity to intermediate state decay
 - Possibility of working with levels in continuum



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Abbreviation Motivation Theory General Physics Nuclear physics

STIRAP in General Physics

- On the other side of the coin
 - Power

$$\Omega_{\max} T \geq 10$$

$$|\Omega_{\max}|^2 T \geq \left[1 + \frac{\Delta\omega}{\Delta\omega_{TL}} \right] \frac{50}{T}.$$

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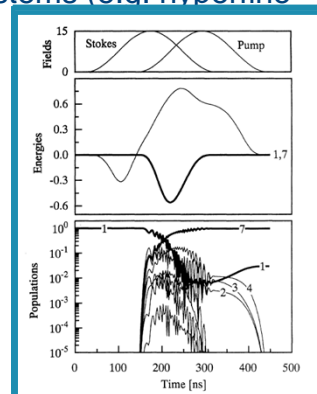
J. Martin et al. Phys. Rev. A
(1995)

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Abbreviation Motivation Theory General Physics Nuclear physics

STIRAP in General Physics

- On the other side of the coin
 - Power
 - Interference in multilevel systems (e.g. hyperfine interaction)
 - = 3-step procedure
 - Adiabaticity
 - Connectivity
 - Eigenvalue interactions



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J. Martin et al. Phys. Rev. A
(1995)

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STIRAP in General Physics

- On the other side of the coin
 - Power
 - Interference in multilevel systems (e.g. hyperfine interaction)
 - = 3-step procedure
 - Adiabaticity
 - Connectivity
 - Eigenvalue interactions
 - Decay intermediate state (system dependent)

$$(\Gamma T \lesssim 10)$$

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J. Martin et al. Phys. Rev. A
(1995)

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STIRAP in General Physics

- STIRAP is widely applied in
 - Matter-wave optics

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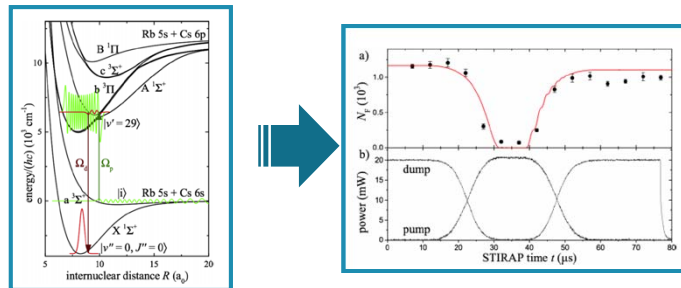
L. S. Goldner et al. Phys. Rev. Lett.
(1994)Takekoshi et al. Phys. Rev. Lett.
(2014)A. S. Parkings et al. Phys. Rev.
Lett. (1993)

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Abbreviation Motivation Theory General Physics Nuclear physics

STIRAP in General Physics

- STIRAP is widely applied in
 - Matter-wave optics
 - Atomic and molecular physics
 - Atoms – molecule conversion (e.g. Ultracold molecular gases)



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A. S. Parkings et al. Phys. Rev. Lett. (1993)

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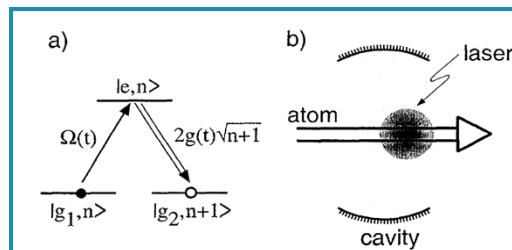
Takekoshi et al. Phys. Rev. Lett. (2014)

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STIRAP in General Physics

- STIRAP is widely applied in
 - Matter-wave optics
 - Atomic and molecular physics
 - Atoms – molecule conversion (e.g. Ultracold molecular gases)
 - Preparing photon number



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STIRAP in Nuclear Physics

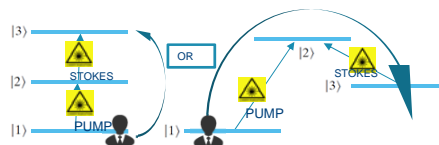
- Applications possible in Nuclear Physics work
 - Replacing optical pumping: STIRAP can
 - Reduce interaction region
 - Include 'open' systems
 - Efficient ionization: STIRAP can
 - Efficiently excite ensemble to auto-ionising level?
 - Doppler ensemble
 - In case that transition frequencies are not too far apart → excite efficiently entire Doppler ensemble?
 - Polarization of the beam

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STIRAP in Conclusion

- Efficient and robust excitation between quantum levels
- Applied in a variety of physics applications
- Can we use it ?



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Thank you for your
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